11. RELAY FUNCTIONALITY REVIEW

11.1 INTRODUCTION

As part of the seismic evaluation of DOE facilities, it may be necessary to perform a relay seismic functionality review. The purpose of this review is to determine if the equipment listed on the Seismic Equipment List (SEL), as described in Chapter 4, could be adversely affected by relay malfunction in the event of a Design Basis Earthquake (DBE) and to evaluate the seismic adequacy of those relays for which malfunction is unacceptable. The term "relay malfunction" is used to designate relay chatter or inadvertent change-of-state of the electrical contacts in a relay, motor starter, or switch. The purpose of this section of the DOE Seismic Evaluation Procedure is to provide an overview of the relay evaluation procedure and describe the interfaces between other activities described in the DOE Seismic Evaluation Procedure and the relay evaluation.

Information on a detailed procedure for evaluating relays is contained in Section 6 of the SQUG GIP (Ref. 1) and in its supporting documents. The SCEs and relay evaluation personnel should not use the material in this chapter unless they have thoroughly reviewed and understood the information in Section 6 of the SQUG GIP and its supporting documents. The DOE Seismic Evaluation Procedure contains a condensed version of the detailed procedure in the SQUG GIP. In Sections 11.2 through 11.5, the relay functionality review is intended to identify most of the essential relays that should be evaluated, to provide the procedure for evaluating those relays, and to be a cost effective approach for identifying "bad actors". Section 11.2 discusses three methods for establishing the seismic capacity of relays and includes a list of low ruggedness relays. Section 11.3 provides two methods for determining the seismic demand on relays mounted in cabinets or other structures. The seismic capacity is compared to the seismic demand using the guidelines of Section 5.4. Section 11.4 provides information for conducting a walkdown as part of the relay evaluation. This walkdown can be incorporated as part of the Screening Evaluation and Walkdown described in Section 2.1.3. Finally, Section 11.5 discusses techniques for resolving relay outliers.

11.2 SEISMIC CAPACITY OF RELAYS

11.2.1 <u>Generic Seismic Test Data</u>[1]

Seismic test data is available on a variety of types of relays. These data have been reduced to Generic Equipment Ruggedness Spectra (GERS) in Reference 44 which define seismic acceleration levels below which relays can be expected to function without chatter or other damage. The GERS are seismic response spectra within which a class or subclass of relays has functioned properly during shake-table tests. In some cases the GERS are based on "success" data (that is, seismic test spectra for which no relay malfunction occurred). In this case, the test spectra for one or more relays in a given class represent a lower bound of the seismic ruggedness of the class. In other cases, the GERS may be based on "fragility" data as the seismic response spectra in which failures or malfunctions occurred. In this case, the GERS represent an upper bound of the seismic ruggedness of the relay class. Where both success and fragility data are available for a given relay class, the GERS fall between the two spectra. Engineering judgment was used in developing the GERS level to smooth out sharp peaks and valleys in the test response spectra.

An example GERS for several auxiliary relay types is shown in Figure 11.2-1. A normalized GERS shape is illustrated at the top of this figure and GERS levels (i.e., the peak acceleration) for example relays are tabulated at the bottom of this figure. Complete sets of all available GERS for relays are given in Reference 44.

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[1] Based on Section 6.4.1 of SQUG GIP (Ref. 1)

11.2.2 Earthquake Experience Data[2]

Data have been obtained on relay performance, specific failures, relay vulnerabilities, and other information from actual earthquake experience in industrial power plants and other facilities which have undergone significant earthquakes. This information has been used to identify unacceptable relay types such as those which are known to be susceptible to damage or chatter due to moderate shaking. Unacceptable relays and related contact devices that must be avoided are listed and considered in the screening procedure given in Reference 45. Based on earthquake experience data and on test data, solid state relays and mechanically-actuated switches are considered seismically rugged and need not be evaluated for relay chatter. Details and restrictions regarding the screening of both the low-ruggedness and high-ruggedness classes of control circuit devices are described in Reference 45.

Table 11.2-1 from Appendix E of Reference 45 provides a list of low ruggedness relays, or "bad actors". The relay evaluation procedure seismic demand determination and GERS cannot be applied to these relays because of their low seismic ruggedness or demonstrated sensitivity to high frequency vibration. Relays listed in Table 11.2-1 should be classified as outliers and case specific techniques or current qualification techniques must be utilized to demonstrate the adequacy of these relays.

11.2.3 Relay-Specific Test Data[3]

The GERS and earthquake experience data discussed above are expected to apply to many of installed relay types in essential circuits. Facility-specific and relay-specific seismic test data, where available, can also be used. This seismic test data is generally maintained by specific facilities and/or relay suppliers and has not been included in the relay GERS. It may be used on a relay-specific or facility-specific basis.

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[2] Based on Section 6.4.1 of SQUG GIP (Ref. 1)

[3] Based on Section 6.4.1 of SQUG GIP (Ref. 1)

Table 11.2-1 Low Ruggedness Relays (Appendix E of Reference 45)

RELAY	OPERATING MODE	REFERENCES
GE CFD	All	1 (81-14/313, 82-26/348, 86-13/293, 2, 3, 4, 5 (IN 85-82), 6
GE CFVB	All	2, 3, 6
GE CEH	All	2, 6
GE CPD	All	2, 6
GE IJD+ (non 1E)	All	2
GE PVD 11 and PVD21	All	1 (84-20/352, 3, 4 (GE)
GE RAV11	All	4 (GE)
GE HGA	(DE, NC)	1 (84-18/331, 86-15/269, 87-11/250), 4, 5, (IN 88-14)
GE BFA65	All	4 (BNL)
W HLF	All	2, 6
W HU (non 1E)	All	3, 6
W ITH	All	1 (81-44/346 NS 81-37/346)
W ARMLA	All	5 (IN 82-55)
W PMQ	All	1 (85-16/247)
W SG	(DE, NC)	4 (ANCO)
W SV	All	4 (BNL)
W SC	All	4 (BNL)
W SSC	All	4 (BNL)
W COM-5 (Non 1E)**	All	4 (W)
ASEA ARMX-L	All	1 (88-06/387)
English Electric YCG+	All	2
Mercury Switches	All	1 (86-25/249), 2
Sudden Pressure Switches $^{\pi}$	All	2

References:

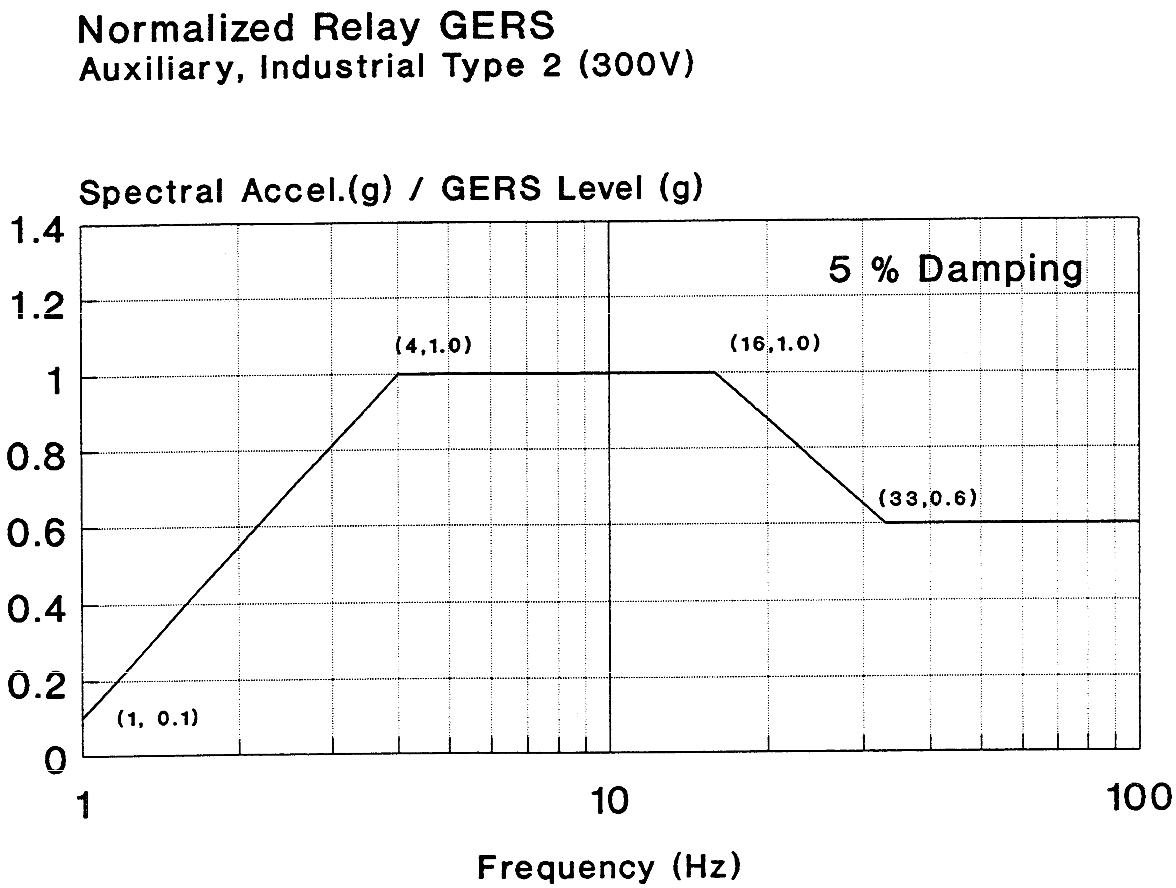
1. LERS
2. Earthquake Experience Data
3. SAFEGUARDS Data
4. IEEE 501 Test Data
5. Notices, Bulletins, etc.
6. Induction cup or induction cylinder design

* DE = De-energized
E = Energized
NC = Normally Closed Contact
NO = Normally Open
All = All Modes

\+ Damage has occurred to this relay in an earthquake and it must be assumed that it will be inoperable following a DBE level earthquake.

π Transformer pressure surge sensing devices

** With SSC-T IITH unit



Type and Submodel Identification	GERS Level[1] Non-Operate NO[2]	NC[2]	Operate NO/NC[2]
Make #1, Model A	10	9	10
Make #2, Model A	10	9	10
Make #2, Model B	10	-[3]	10
Make #3, Model A	10	9	10
Make #4, Model A	10	5	10
Make #5, Model A	10	10	10

1 "GERS Level" is the spectral acceleration (g) from 4 to 16 Hz for 5% damping.
2 "NO" = Normally Open; "NC" = Normally Closed; "NO/NC" = Change State.
3 "-" = Data not available.

Figure 11.2-1 Generic Equpment Ruggedness Spectra (GERS) for Auxiliary Relays (Reference 44) (Figure 6-2 of SQUG GIP, Reference 1)

11.3 SEISMIC DEMAND ON RELAYS

This section has two methods for determining the seismic demand on relays. Seismic adequacy of essential relays can be confirmed by successful application of either one of these methods. Details on the methods for determining seismic demand on relays is contained in Section 6 of the SQUG GIP (Ref. 1) and in its supporting documents. After computing the seismic demand on the relays, the demand is then compared to the seismic capacity (discussed in Section 11.2) using the guidelines of Section 5.4.

11.3.1 Use of In-Cabinet Amplification Factors[4]

The first method for determining relay seismic demand is based on: (1) using a Seismic Demand Spectrum (SDS) at the base of the cabinet containing the relay and (2) multiplying this spectrum by an in-cabinet Amplification Factor (AF). To use this method, the essential relay should not be one of the low-ruggedness types listed in Table 11.2-1. The seismic demand on relays can be represented by an In-cabinet Demand Spectrum (IDS) which is computed using the following equation:

$$IDS = SDS \times AF$$

Where:

SDS - Seismic Demand Spectrum (SDS) as described in Section 5.2.3. The SDS is a scaled in-structure response spectrum computed from the DBE.

AF - in-cabinet Amplification Factor, as given in Table 11.3-1, for various types of cabinets. The guidelines and criteria for identifying the various cabinet types are included in Appendix I of Reference 45.

A relay is considered seismically adequate if the IDS is bounded by the relay capacity spectrum in the frequency ranges from 4 - 16 Hz and from 33 Hz and above, i.e., the zero period acceleration (ZPA). If the guidelines for this method cannot be applied, or the seismic demand is not bounded by the seismic capacity of the relay, then the following method can be used instead.

[4] Based on Section 6.4.2 of SQUG GIP (Ref. 1)

Table 11.3-1 In-Cabinet Amplification Factors for Use with Section 11.3.1 (Table 6-2 of SQUG GIP, Ref. 1)

Type of Cabinet	In-Cabinet Amplification Factor (AF)[1]
MCC-type cabinet (defined in Appendix I of Reference 45)	3
Conventional control panel or benchboard (defined in Appendix I of Reference 45)	4.5[2]
Switchgear-type cabinet or similar large unsupported panel (defined in Appendix I of Reference 45)	7
Other type of cabinet, panel, or enclosure for which cabinet-specific amplification data exists	[3]

1 The SCEs and relay evaluation personnel should not apply these amplification factors unless they have thoroughly reviewed and understood the information in Section 6 of the SQUG GIP (Ref. 1) and its supporting documents such as References 43 and 45.

2 To use an amplification factor of 4.5, the control panel or benchboard must meet the restrictions (or caveats) given in Reference 45, Appendix I, except that a 13 Hz lower bound fundamental frequency shall apply instead of the 11 Hz fundamental frequency specified by the relevant caveat in Reference 45, Appendix I, when assessing:

devices located on internal independent racks,

cantilevered appendages, such as cantilevered wing walls attached to a front face or side wall, and

access doors which are part of a control panel or benchboard.

Note that one intent of the control panel and benchboard caveats is to restrict use of this amplification factor to only those cabinets and panels which have all significant natural modes at 13 Hz and higher. The amplification factor is a function of the panel frequency with the most flexible panel mode typically being the diaphragm, or out-of-plane, mode.

3 For the "Other" type of cabinets, an effective broad-based amplification factor can be developed from appropriate test data. Reference 43 can be used for this purpose as a guide in which an effective in-cabinet amplification factor can be obtained by multiplying the measured peak amplification factor, for the location in the cabinet where the relay is mounted, times an appropriate reduction factor. Appropriate reduction factors are discussed in Reference 43; for typical, narrow peak amplification spectra, the reduction factor is 0.6.

11.3.2 Use of In-Cabinet Response Spectra[5]

In this method, the technique of computing relay seismic demand is the same as in Section 11.3.1 (i.e., the demand spectrum is bounded by the capacity spectrum in the frequency ranges from 4 - 16 Hz and from 33 Hz and above) except that instead of using an in-cabinet amplification factor to determine the seismic demand on the relay, an in-cabinet response spectrum is used. To use this method, the essential relay should not be one of the low-ruggedness types listed in Table 11.2-1. For comparison to relay capacity spectrum, the in-cabinet response spectrum can be treated similar to the IDS of Section 11.3.1. There are two methods for developing in-cabinet response spectra, depending upon the type of equipment:

Control Room Benchboards and Panels. An amplified, in-cabinet response spectrum can be determined using the methodology and software described in Reference 43 for control room benchboards and panels. In this option, the cabinet or panel evaluated must meet the restrictions (or caveats) given in Reference 43. A 13 Hz lower bound frequency shall apply instead of the 11 Hz fundamental frequency specified by the relevant caveat in Reference 43 when assessing devices located on internal independent racks, cantilevered appendages such as cantilevered wing walls attached to a front face or side wall, and access doors which are part of a control panel or benchboard. Note that one intent of the control panel and benchboard caveats is to restrict use of this amplification factor to only those cabinets and panels that have all significant natural modes at 13 Hz or higher. The use of Reference 43 software should not be extended to other classes of equipment without the review and approval of the DOE.

Other Types of Equipment. For other types of cabinets and panels that are not covered by Reference 43, in-cabinet response spectrum can be determined using analytical and/or test methods which are suitable for the specific case. These other methods should be justified in the documentation of the Relay Functionality Review. This is equivalent to the case-specific analysis and/or test approach. Caution should be exercised when using this method to determine in-cabinet response spectra by considering the effects of local flexibility and mounting details such as local plastic deformation, slotted holes, fitted connections, etc.

11.4 RELAY WALKDOWN[6]

Information on a detailed procedure for conducting relay walkdowns is contained in Section 6 of the SQUG GIP (Ref. 1) and in its supporting documents. The SCEs and relay evaluation personnel should refer to the details in these documents when conducting relay walkdowns. A walkdown should be performed as a part of the relay evaluation. The purposes of the relay walkdown are to:

- Obtain information needed to determine cabinet types which house essential relays and to determine the in-cabinet amplification, where needed, for the seismic capacity methods described above.
- Evaluate the seismic adequacy of the cabinets or enclosures which support the essential relays.
- Spot check mountings of essential relays.
- Spot check the essential relays to evaluate their types and locations, including checks for vulnerable relays (as listed in Table 11.2-1).

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[5] Based on Section 6.4.2 of SQUG GIP (Ref. 1)
[6] Based on Section 6.5 of SQUG GIP (Ref. 1)

These purposes can be accomplished during one walkdown or separately during different walkdowns. To accomplish the first purpose of the relay walkdown, the cabinets or panels which house essential relays should be identified and the information needed to determine in-cabinet amplification should be reviewed. A SCE and a Relay Reviewer (as discussed in Section 3.3.3) should accomplish this purpose. The serial and model number of the relays should be compared with the applicable relay numbers in References 43 and 45.

The second purpose, evaluation of the seismic adequacy of the cabinet or enclosure supporting the relay, should be done as a part of the Screening Evaluation and Walkdown as described in Section 2.1.3. Note that the cabinets or enclosures supporting essential relays should be identified prior to this walkdown.

The third purpose of the relay walkdown is to spot check relay mountings to confirm that relays are mounted in accordance with manufacturer's recommendations. The objective of the spot checks is to identify any abnormal or a typical relay mounting techniques. The specific number of relays to be checked is not quantified because the bulk of the relays addressed in the relay evaluation procedure are typically located in a few specific facility areas and can be easily checked. Most of the relays encountered in the relay evaluation can be checked by opening relay cabinets in the following areas:

- Control room
- Relay room or auxiliary control room
- Switchgear rooms
- Diesel generator control panel area

Spot checking relay mountings can be performed during a separate relay walkdown by personnel familiar with relay installation. Alternatively, relay mountings may be spot checked during the seismic walkdown when in-cabinet amplification information is gathered. Special preparation or training is not required for spot checking relay mountings. Indications such as proper relay label orientation, mounting bolts in place and tight, and whether the relay is snug in its mounting bracket are sufficient to judge the adequacy of the mounting; analytical checks are not intended except as a means to evaluate atypical mountings.

The fourth purpose of the relay walkdown is to confirm relay types and locations. This can be performed at the same time that the relay mountings are checked and by the same individuals. The approach for confirming relay types by the relay walkdown team includes noting relay types observed in the cabinets and then comparing this with the relays identified on electrical drawings. It is important to note that relay mountings are considered to be standard and the circuit drawings are assumed to be correct and up-to-date. Spot checks of the relay mountings and relay types are a mechanism to confirm these assumptions. Any significant spot check discrepancies will necessitate more thorough relay inspections.

11.5 OUTLIERS[7]

An outlier is defined as an essential relay which does not meet the guidelines for:

- Relay seismic capacity and seismic demand as given in Sections 11.2 and 11.3
- Relay mounting as given in Section 11.4

Chapter 12, Outlier Identification and Resolution, is used when an outlier is identified and the cause(s) for not meeting the guidelines should be documented with the Outlier Seismic Evaluation Sheet (OSES) provided in Chapter 13. Methods are given in this section for use as a generic basis to evaluate the seismic adequacy of essential relays. Therefore, if an essential relay fails these generic methods, it may not necessarily be deficient for seismic loading; however, additional evaluations are needed to show that it is adequate. Some of the additional evaluations and alternative methods for demonstrating seismic adequacy are summarized below.

- Refine the seismic requirements and/or analyses.
- Test the relay and/or the cabinet in question.
- Re-design and modify the circuit to make the relay function nonessential.
- Relocate the relay to reduce the seismic demand imposed upon it.
- Replace the relay with a seismically qualified one.
- Stiffen the relay mounting.
- Use other justifiable approaches.

Generic methods for resolving outliers are also discussed in Chapter 12.

[7] Based on Section 6.6 of SQUG GIP (Ref. 1)